FINAL REPORT

Impact of Roads in Recreational Developments on Forest Environment

by

Robert S. Freeburg

Agricultural Engineering Department

and

Bruce A. Buchanan

Agronomy Department

New Mexico State University

Las Cruces, New Mexico 88003

Cooperative Agreement 16-423-CA

Research Work Unit FS-RM-1901

NMSU Project 4111-144

January, 1976

ACKNOWLEDGMENTS

The authors acknowledge with appreciation the following:

Aid and subdivision information supplied by Bill McLean of Cloud Country, Jim Manatt of Ponderosa Pines, and Oscar Black of Western Estates. Soil survey information supplied by Gene Ashford, U.S. Forest Service, Alamogordo, N.M.

Drafting by Phil Heick, New Mexico State University. Manuscript preparation by Tess Bonk, New Mexico State University.

Aid and advice of numerous U.S. Forest Service personnel, particularly at the Rocky Mountain Forest and Range Experiment Station, Albuquerque District Office, and the Mayhill Ranger Station.

Water supply information provided by the Alamogordo Office of the New Mexico Environmental Improvement Agency.

This work was accomplished under a grant from the Eisenhower Consortium, according to Cooperative Agreement 16-423-CA, Research Work Unit FS-RM-1901 between the U.S. Forest Service and New Mexico State University.

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INTRODUCTION

There has been extensive development of vacation-home communities in the past few years. Development pressures have been increasingly concentrated in forested areas of the Southwest because of the natural attractions of the forests and the growth in population surrounding these areas. In fact, due to the contrast in climate between the forested areas and their surroundings in the Southwest, many of these areas are more fully developed than are their counterparts in other sections of the West. For instance, in 1964 the Lincoln National Forest, surrounded by desert and semi-arid regions with five million people living within 500 miles of the forest, was more fully developed than were other areas of New Mexico (Gray and Anderson, 1964b). The rate of growth in recreational uses of this type of area is illustrated in the prediction that persons visiting the Ruidoso (now known as the Smokey Bear) Ranger District of the Lincoln National Forest would increase from 300,000 in 1960 to 2,000,000 by the year 2000 (Gray and Anderson, 1964a).

Recreation contributes heavily to the economy of the forested areas. Gray and Anderson (1964b) found that in 1962 the value of recreational uses in the Ruidoso Ranger District was 70 percent of the total annual gross value of the resources used in an area within 500 miles of the district. At that time, less than one percent of the gross value was attributed to "cabin ownership" (maintenance and other annual costs). Since that time, however, numerous vacation-home developments have been established and the value of individual "cabins" has risen dramatically.

Altogether, the attractiveness of the forested areas, population growth, and economic growth are producing increasing pressure for greater vacation-home development.

Poorly developed vacation-home communities can have detrimental effects on their own and surrounding environments. Layout and construction of the roads and associated services can have significant impact on landscape aesthetics, drainage, and erosion.

In face of heavy developmental pressure and potential detrimental effects of development, it is important that developers and managers of vacation-home communities have information with which to minimize adverse impacts on the forest environment.

Description of Study Areas

Two recreational subdivisions in the Lincoln National Forest of south-central New Mexico were studied to determine the impacts of their roads in the environment.

The location of these subdivisions relative to Cloudcroft, N. M., the nearest town, is shown on the Cloudcroft Quadrangle Map, U.S.D.I., Geological Survey in the Appendix. Maps of the study areas within the subdivisions are presented in figures 1 and 2.

One of the subdivisions, Ponderosa Pines, located approximately eight miles southeast of Cloudcroft in Cox Canyon, is pictured in figure 3. It was in the early stages of development at the beginning of the study. Roads had been roughed out, and refined grading, filling, and surfacing were in progress during most of the study. A golf

Fig. 1. Site map of Cloud Country Subdivision

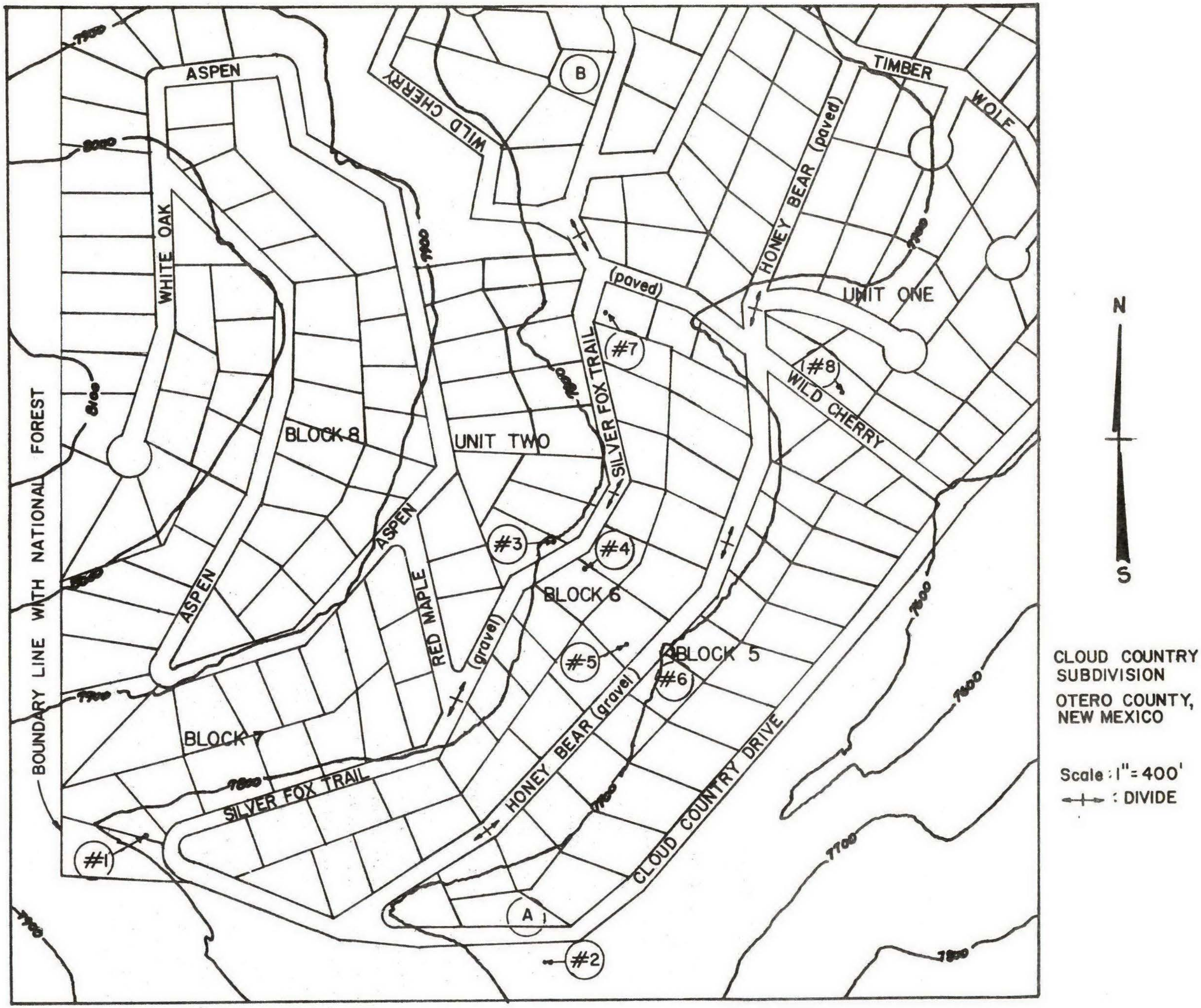


Fig. 2. Site map of Ponderosa Pines Subdivision

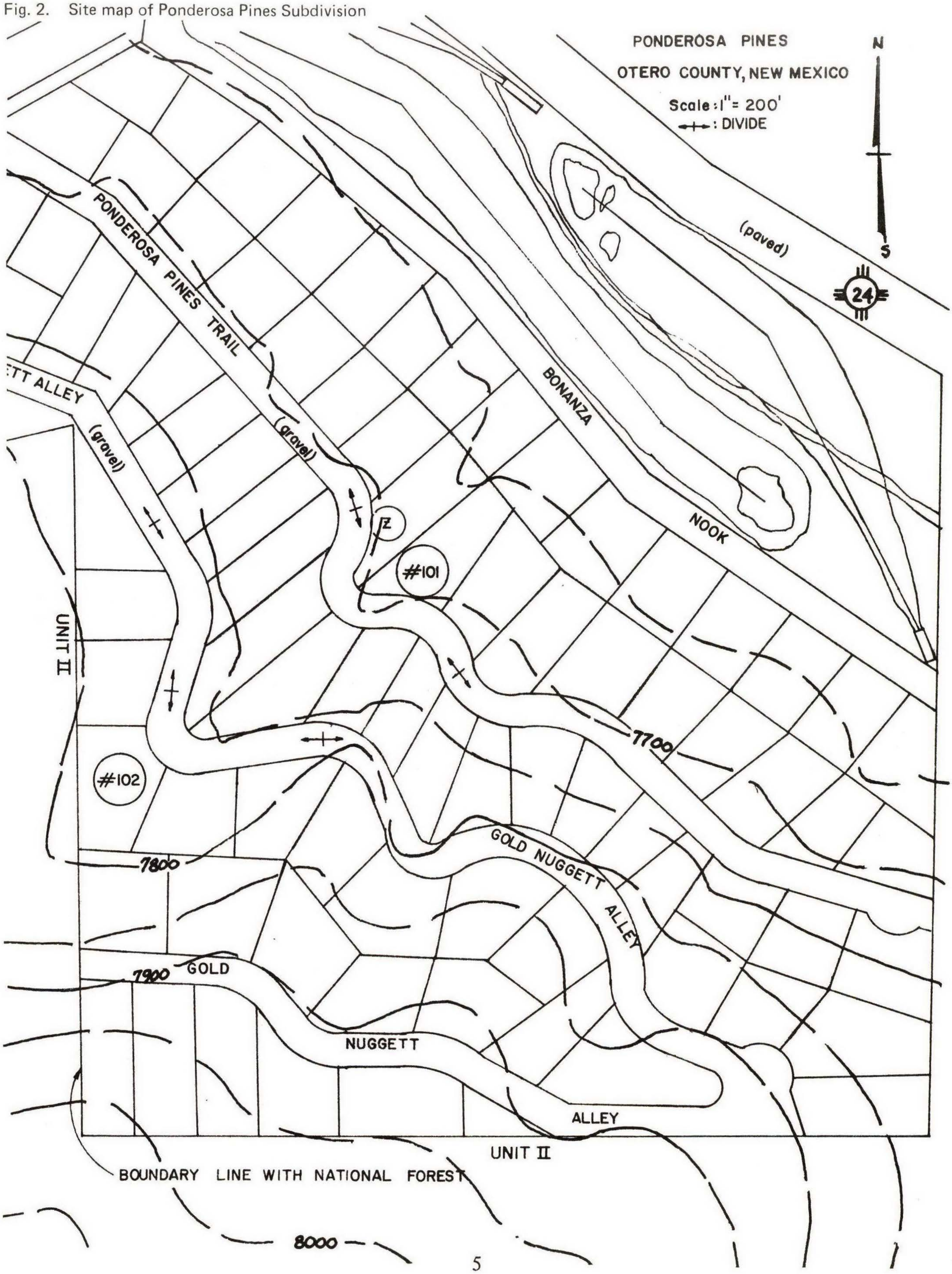


Fig. 3. Site of Ponderosa Pines Subdivision. Golf course is in foreground. Roads are well screened by trees.

course, with club house, was being developed during the study period. A fishing pond was already in existence near a model home. Utilities, primarily electrical, were installed in part of the subdivision during the study period.

The second subdivision, Cloud Country, pictured in figure 4, is located east of Cloudcroft in James Canyon. It was at a later stage of development at the initiation of the study. A recreation hall, horse stables, and tennis courts were in existence. Golf and other amenities were available at a company-owned lodge in Cloudcroft. During the study, a fishing pond, a swimming pool, and a landing strip were developed. All of the roads had been roughed out and some were paved at the beginning of the study. Several houses were in various stages of construction. Most of the original buildings belonging to the ranch from which the project was developed were in use for engineering, maintenance, and sales purposes. Utilities, consisting of a water and fire system, electrical system, sewage system, and telephone system were being installed at the beginning of the study period and this work continued through the period.

The subdivisions were similar in most aspects of their engineering design. Lots are approximately one-quarter acre in size. The roads in Ponderosa Pines had been routed by placing all possible

Fig. 4. Site of Cloud Country Subdivision. Recreation hall is at far left, fishing pond at right. Roads and homes are well screened by trees.

major sections on contours, thereby minimizing lengths of connecting, cross-contour sections.

The clientele for both subdivisions was derived primarily from the same zone as the recreationists in the Lincoln National Forest, as described in the Introduction. However, some purchasers of homes, particularly in Cloud Country, resided out-of-state (mostly in Texas) and a few out of the United States (mostly in Mexico).

Both study areas are situated on the northeast-facing side of their valleys. Development of each was concentrated within the timber stands. Timber consists of intermixed Douglas fir, white fir, and ponderosa pines. Some Gambel oak is also present, particularly at Ponderosa Pines. For the most part, clearings among the trees are well sodded with perennial grasses.

Each subdivision is bounded generally on the south and west by Forest Service lands.

Deer and wild turkeys are important in the wild life population of the area.

Yearly precipitation is approximately 20 inches.

Elevation at the subdivisions varies from 7500 to 8000 feet above sea level.

Description of Experimental Method

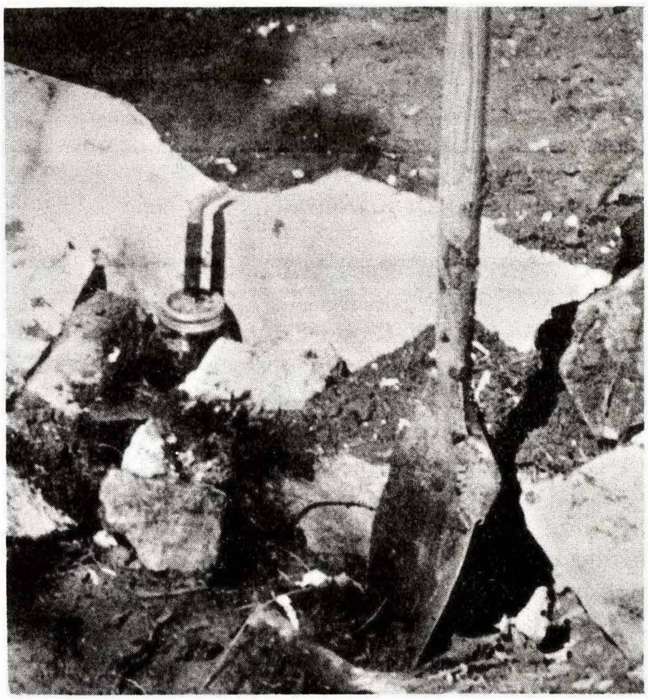
Inexpensive sediment samplers and precipitation gauges were installed on the two subdivisions near Cloudcroft. Each precipitation gauge, (figure 5) consists of an aluminum can open at the top and funneled at the bottom which collects the precipitation and passes it to a plastic storage bottle in a well beneath the can. The amount of precipitation collected is determined by measuring the volume in a graduated cylinder and applying a calibration factor to obtain inches of precipitation. The gauges were installed in pairs to provide a check.

Sediment samplers of the type shown in figure 6 were designed and tested for this project. They consist of a ventilated plastic elbow attached to the top of a canning jar. These samplers performed well when installed either in a channel bed or on a V-notch weir. Observations during rainstorms showed that the samplers usually fill at only one stage of flow; i. e., immediately after the water surface reaches the throat of the ell. This characteristic of the samplers is significant in interpreting the size distribution of the collected samples. Doty and Carter (1965) noted that clay-sized particles are usually high at the beginning of a runoff event and decrease as the soil-loss rate increases, while the reverse is true for silt-sized particles. Thus, these samplers are expected to emphasize the clay over the silt fractions.

Fig. 5. Inexpensive precipitation gauge

In the Cloud Country subdivision, two of the inexpensive precipitation pairs of gauges were installed. These are labeled A and B in figure 1. A standard recording precipitation gauge was also installed at Cloud Country headquarters after the study was underway. It was used as a check on the other two stations. Eight sediment sampling stations, including control, were established at Cloud Country.

Fig. 6. Sediment sampler



In Ponderosa Pines, one precipitation station (Z on figure 2) and three sediment sampling stations, including control, were established. One of the sediment sampling stations was abandoned early in the study because of the difficulty of maintaining consistent flows over the weir.

The precipitation and sediment samples collected during 1974 were analyzed in the laboratory for the following:

1. Percent solids (weight as percent of sediment and water)
2. Electrical conductivity of filtered water (conductivity bridge)
3. pH of filtered water (potentiometrically)
4. Water soluble cations (atomic absorbtion)
   Calcium
   Magnesium
   Sodium
   Potassium
5. Texture of solids (pipette and sieve analysis)

Sediment samples collected during 1975 were analyzed for percentages of sand, silt, and clay.

The major soil types in each subdivision were described with the aid of the soils scientist from the U. S. Forest Service. Those soils that seemed to represent the dominant soil series of the area, as observed from the road cuts, were described.

Slopes were measured with Abney levels to determine how much of the runoff came from the road to the sediment samplers. A weighted average of slope was obtained by calculating the length of road and associated slope that accounted for the total length of road contributing runoff to sampling sites.

A projected subdivision south of Mesilla Park, New Mexico, Western Estates, was used to study the percentage of roads in several subdivision configurations.

RESULTS AND DISCUSSION

Part I. Analysis of Physical Effects

Sampling sites 1 (Cloud Country) and 102 (Ponderosa Pines) were situated upstream from the construction area and were installed as control sites, (figures 1 and 2). Each was positioned within 250 feet of the boundary between the project and the National Forest land. Sampling sites 2, 4, 6, and 8 (Cloud Country)and 101 (Ponderosa Pines) were positioned immediately below the roads being monitored (figures 1 and 2). Sampling site 3 was positioned to represent a control to sites 4, 5, and 6. However, no runoff occurred at this site until late in the study (figure 1 and table 2). Sampling site 2 in Cloud Country was located at the bottom drainage point of a length of gravel road running transverse to the contours. Sampling site 8 in Cloud Country was located at a bottom drainage point of a length of paved road also running transverse to the contours. Thus, sites 2 and 8 were intended to provide a comparison between gravel and paved, non-contoured roads (table 1). Sites 4, 6, and 7 in Cloud Country and site 101 in Ponderosa Pines were intended to represent the contoured, gravel road condition (table 1). As can be seen by comparing the location of the 7800-foot and 7700-foot contours with the road location in figures 1 and 2, the roads only approximately followed the contours. Thus, with this road layout, sites actually represent generally-contoured but variable-slope roads. The variation between the road and the contours at site 7 in Cloud Country was obvious. In some instances, particularly in Ponderosa Pines, some of the variation between the contour and the road was moderated by providing fills across the water courses (see figure 9).

Sediment concentrations, as percentages of total samples, and rainfall amounts at the Cloud Country and Ponderosa Pines subdivisions are presented in tables 2 and 3, respectively. Generally, a rain of approximately three-quarters of an inch was required to produce collectable samples, and then only with intense rainfall.

Sediment concentration differences at sampling sites were compared statistically by t-tests. The degrees of freedom used in each test were provided by the separate runoff-producing rains. These comparisons are summarized in table 4.

In all instances, more sediment was produced at the sampling sites than at the corresponding control sites (table 4, section A). All sediment-production differences between sampling sites and controls were statistically significant. Except at site 4 in Cloud Country, the non-contoured sites tended to produce more sediment than the contoured sites. This trend is seen in a comparison of

Table 1. Characteristics of sampling sites

Site	Location[1]	Weighted Ave. of % Slopes Above Site	Class
2	Cloud Country	10.4	gravel, non-contoured
4	Cloud Country	3.5	gravel, contoured
6	Cloud Country	5.5	gravel, contoured
7	Cloud Country	6.7	gravel, contoured
8	Cloud Country	14.3	paved, non-contoured
101	Ponderosa Pines	5.6	gravel, contoured

[1]See figures 1 and 2 for locations of sites within subdivision.

Table 2. Sediment concentrations, percent of total sample, and rainfall amounts[1] at Cloud Country subdivision

Date	Site								Rainfall, Inches		
	1 (control)	2	3	4	5	6	7	8	Gauge A	Gauge B	Std. Gauge
8/20/74	0.94	9.04	dry	7.28	4.99	4.80	8.54	4.52	1.6	1.4	
8/27/74	2.12	9.30	dry	18.50	7.06	3.25	3.51	6.69	2.3	2.5	
10/01/74	2.2	6.7	dry	48.0	16.1	6.1	4.4	10.5	7.3	8.7	
7/15/75	dry	9.46	dry	14.43	2.06	6.03	5.84	21.34	NR	NR	
7/25/75	dry	dry	dry	dry	dry	dry	dry	dry	0.6	0.9	0.5[2]
8/06/75	dry	15.76	dry	4.76	18.45	12.72	NR	7.21	3.1	4.5	3.4[2]
9/03/75	NR	NR	0.16	6.98	14.72	14.14	30.66	4.22	3.0	4.9	3.1[2]
9/16/75	5.08	24.71	6.74	38.13	10.10	19.76	8.76	23.42	3.4	5.7	5.0[2]
10/14/75	4.65	18.14	5.43	10.42	9.68	2.32	15.99	8.56	0.7	0.8	0.5[2]

NR = No Record

[1]Rainfall amounts are accumulated amounts, in inches, since previous entry.

[2]Standard precipitation gauge at Cloud Country subdivision, installed on 7/15/75.

Table 3. Sediment concentrations, percent of total sample, and rainfall amounts at Ponderosa Pines subdivision[1]

Date	Sampling Site Number		Rainfall, Inches
	101	(Control) 102	Gauge Z
8/20/74	dry	dry	0.7
8/27/74	9.74	dry	2.4
10/01/75	10.00	1.20	7.3
7/15/75	5.44	1.47	7.1
8/06/75	7.95	0.78	2.8
9/03/75	17.51	dry	3.6
9/16/75	19.61	5.52	NR
10/14/75	10.86	dry	0.6

[1]Rainfall amounts are the accumulated amounts, in inches, since previous entry.

the three contoured, gravel-road sites (sites 4, 6, and 7) against the similar but non-contoured site 2. In two of the three comparisons, listed in table 4, section B, the greater production of sediment by the non-contoured, gravel-road sites is statistically significant at the five-percent level. The difference between sites 4 and 2 was not statistically significant.

A comparison between table 1 and table 4, section A, reveals that site 4 had the smallest weighted average slope percentage of the road contributing to runoff to the site but the largest production of sediment. While the difference between site 4 and the non-contoured site 2 was not statistically significant (table 4, section B), it is large

Table 4. Comparison of sediment concentration differences (based on total sample weight)

Location	Average Amount of Sediment (%) Reported as the Difference Between Sampling Site and Reference Site	Reference Site	Sampling Site	Statistical Significance by t-Test
Section A				
Cloud Country	11.2 (#2>#1)	#1, control	#2, non-contoured gravel	**
Cloud Country	18.1 (#4>#1)	#1, control	#4, non-contoured gravel	*
Cloud Country	5.7 (#6>#1)	#1, control	#6, contoured gravel	*
Cloud Country	5.3 (#7>#1)	#1, control	#7, contoured gravel	**
Ponderosa Pines	9.0 (#101>#102)	#102, control	#101, contoured gravel	*
Cloud Country	9.6 (#8>#1)	#1, control	#8, non-contoured, paved	**
Section B				
Cloud Country	6.9 (#4>#2)	#2, non-contoured gravel	#4, contoured gravel	ns
Cloud Country	5.4 (#2>#6)	#2, non-contoured gravel	#6, contoured gravel	*
Cloud Country	5.1 (#2>#7)	#2, non-contoured gravel	#7, contoured gravel	*
Cloud Country	17.0 (#4>#3)	#3, upstream	#4, downstream	*
Cloud Country	8.2 (#4>#5)	#5, downstream	#4, upstream	ns
Cloud Country	1.8 (#5>#6)	#6, downstream	#5, upstream	ns

ns - non-significant

* - significant at the 5% level

** - Significant at the 1% level

enough to invite further investigation. The history of construction near site 4, plotted in figure 12, shows that utility installation in the roadway was being accomplished during both the 1974 and 1975 summers. Rains in August of 1974 and September of 1975 (see table 2) arrived in coincidence with the construction activity to produce large sediment concentrations for those times and a large average concentration for the whole study period. This kind of occurrence was observed at some time or other at each of the sampling sites. The frequent recurrence of this situation is further indicated by the variation between sediment concentrations with time at any given sampling site (tables 2 and 3). In fact, the sediment production from utility construction activities in each roadway overshadowed the sediment production from the road itself.

In addition to utility installation disturbances were those caused by the transport of equipment from one site to another (figure 9). The magnitude of sediment production from this cause could not be separated statistically from that due to other causes, but there was a difference in erosion which could be detected by eye.

The patterns of erosion from roads in the forest have been described by Haupt (1959) and Packer (1967), among others. On-site observations made for this study have, for the most part, verified these predicted patterns.

Haupt reported that the largest statistical importance among several variables affecting the distance that sediment would be transported should be assigned to what he called a slope-obstruction index. The index combined the effects of 1) slopes of the general topography surrounding the road and 2) obstructions which retard erosive water flows. Another variable to which he assigned importance was the interval of cross-drains perpendicular to the centerline of the road. The variables of slope-obstruction index and cross-drain interval together accounted for approximately 90 percent of the distance which sediment would flow from its site of removal. He concluded that gradient along the centerline of the road, when considered alone, had a small effect.

Packer (1967) confirmed the conclusion of Haupt that obstructions on the slopes were a predominant factor affecting the distance of sediment movement. He assigned a relatively small importance to cross-drain interval.

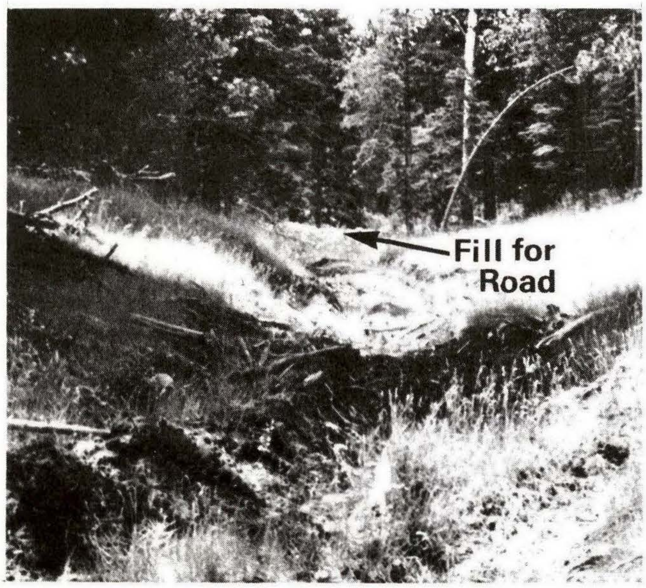
The realization of these concepts of erosion production from runoff are illustrated in figures 7, 8, 10, and 11. Slope of the general topography

Fig. 7. Runoff from non-contoured, paved road above Cloud Country Sampling Site No. 8 during typical summer rainstorm.

Fig. 8. Sediment trap of debris above Sampling Site No. 101 and below Ponderosa Pines Trail

dictates the slope of roads which must be used to connect contoured roads. Obstructions are necessarily removed from these roads. When paving is added, the obstructions to flow are even further diminished. As seen in figure 7, the runoff from such roads can develop erosive flow rather rapidly. While the pavement reduces erosion from the roadway itself, there is a high potential for

Fig. 9. Construction equipment track above Ponderosa Pines Trail.



erosion of the shoulders of the road. The greater the length of such a road section, the greater the development of erosion potential. The result in this case can be seen by comparing, in table 4, section A, the sediment concentration of runoff from the paved non-contoured road (Cloud Country site 8) with that of runoff from the graveled non-contoured road (Cloud Country site 2).

The erosion pattern from a contoured road is shown in figure 10. It can be seen that cross-drains will develop naturally as has the one at the extreme left of the picture. The greater the variation of the road from the contour, the more erosion can be expected of the type shown on

Fig. 10. Erosion pattern from contoured road (Gold Nuggett Alley in Ponderosa Pines) at fill. See Figure 9.

the roadway. The more nearly the road follows the contour, the shorter the expected interval between natural cross-drains and the less expected erosion from the roadway. These expected results were not borne out by the data of tables 1 and 4, however, due to the dominant effects of other construction factors. Some of these factors have already been discussed in reference to Cloud Country site 4. Other factors can be seen in figure 10; namely, the presence of a sizable berm left at the side of the road by the road grader and of considerable natural debris at the side of the road. These obstructions prevented the formation of cross-drains at close intervals.

Two types of obstruction capable of influencing the slope-obstruction index are illustrated in figures 8 and 11. In figure 8, there is an example of the type of debris sediment trap which commonly occurs. Such traps result both naturally and from the road-building process. Their effective-

Fig. 11. Sediment trapped by reservoir above Gold Nuggett Alley fill. (See Figures 9 and 10.) This is below Control Site No. 102 in Ponderosa Pines Subdivision. The outline indicated with chaining pins at the corners encloses the sediment-filled reservoir.

ness in controlling sediment movement is seen in table 4b in the comparison between Cloud Country sites 4 and 5. In figure 1 it is seen that site 4 is upstream from site 5 a distance of approximately 300 feet. As seen in table 4b, however, the high sediment concentration at site 4 was not transmitted downstream to site 5. Instead, in the 300 feet between the two sites, the sediment concentration was reduced.

The second type of obstruction, illustrated in figure 11, is a reservoir produced by fills which bring the roadway to grade. Such reservoirs contribute significantly to controlling sediment transport until they are filled with sediment. Their maximum capacity coincides with the time of high sediment production immediately after road construction. The effects of these reservoirs are reflected in the relatively low sediment concentration seen at the early dates in tables 2 and 3.

The "self-healing" capabilities of the forest environment, which were frequently observed, were evidently due in large part to these two types of obstructions. These capabilities presumably will work to progressively reduce sedimentation. Such was found by Leaf (1966) to be true for the effects of timber harvest. A trend in this direction is seen in figure 12.

Part II. Evaluation of Chemical and Biochemical Effects

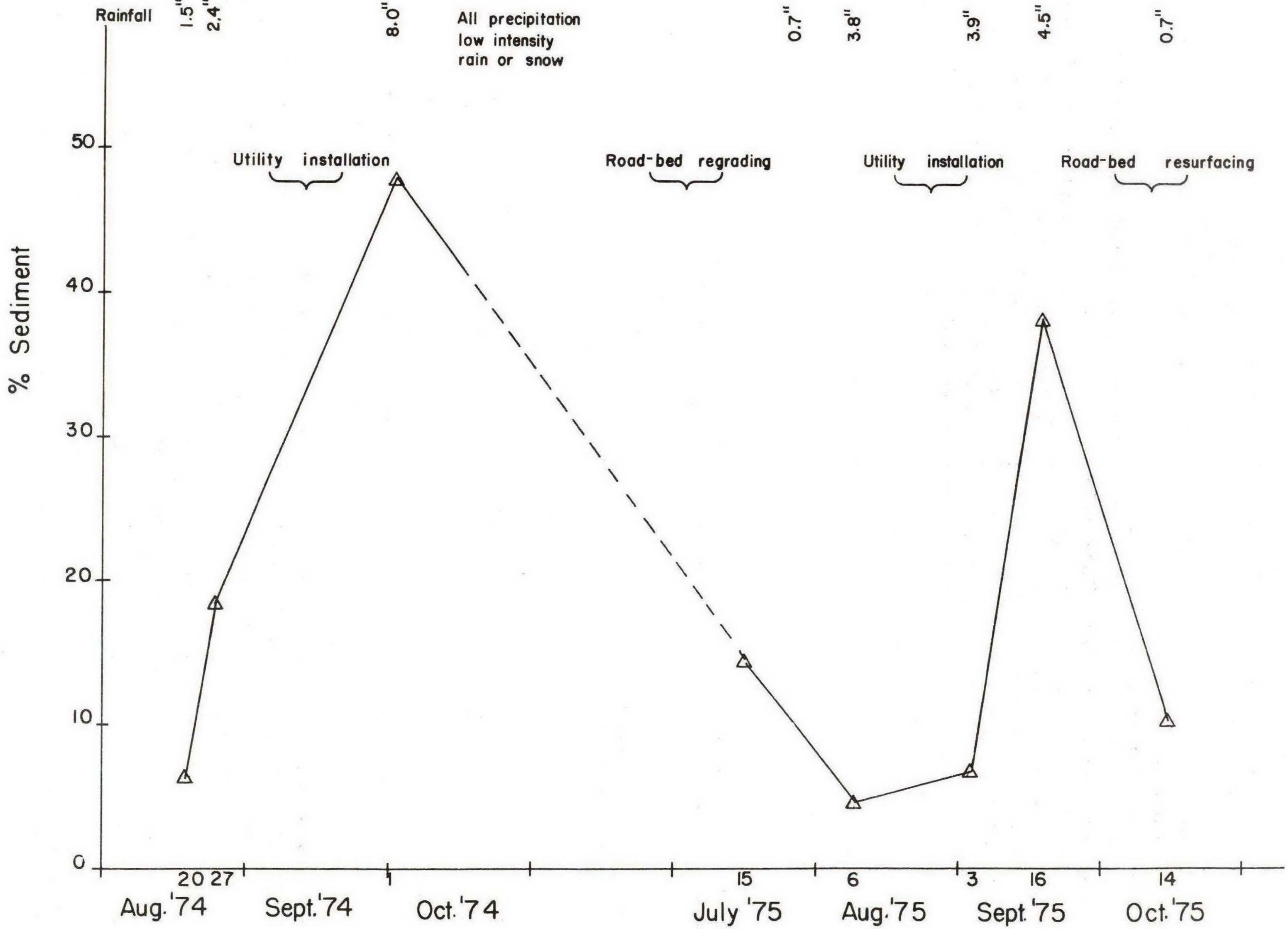
The filtering actions of soils are well known. As an example, Bouwer et al. (1971) measured the quality of sewage effluent and compared it to the quality of water in a nearby well. The sewage traveled 8 feet from a basin to the water table, then 22 feet to the bottom of the well, meanwhile moving 10 feet horizontally. The time required for the travel was approximately two weeks. During the course of that travel, the pH of the water changed from 7.9 to 7.2, the dissolved salts went from 1020 mg/1 to 1060 mg/1, and the fecal coliform (MPN/100m1) went from 10^6 to an average of 20 (usual range of 0-100).

Communication between surface runoff and potable water supply was considered improbable for the subdivisions studied because of the depths of the wells used. The central well presently being used at Cloud Country is 560 feet deep. In Ponderosa Pines, where individual wells are utilized, the depth range is 300 to 350 feet. Coliform counts taken by the Environmental Improvement Agency of New Mexico at Cloud Country have supported this premise. Results of tests made in September, 1974 on samples taken from a spring and a well both showed zero coliform colonies and a fecal coliform count of less than 1 per 10 ml. of water.

That portion of the sediment-carrying runoff which eventually percolated to the groundwater was not expected to produce a detrimental effect because of its own chemical quality. The runoff water from Ponderosa Pines and Cloud Country was quite similar (table 6). Runoff water was similar to the drinking water in pH but lower in soluble salts and lower in hardness.

The precipitation analyzed was slightly acid and very low in soluble salts, compared with the drinking water or runoff (table 5). Both the drinking water and runoff are slightly alkaline and very similar with respect to Ca, Na, and K content. The drinking water sample has a very high Mg content which is reflected by the high electrical conduc-

Fig. 12. Construction history at Cloud Country Sampling Site No. 4.



tivity measure (table 5). Generally Ca content was twice the Mg content in water samples. The Ca and Mg ratio for this sample suggest the groundwater is being supplied with Mg, possibly from a dolomite substratum. Runoff samples are very similar with respect to the cations measured and texture of the sediment (table 5). Surface soils of the area are dominantly clay loams whereas these samples were silty clay loams. The samples have less sand than the soils of the study area; therefore, sand was not being moved by the runoff to the extent that silt and clay were being moved.

The pH, soluble salts content, and total hardness as $CaCO_3$ was measured for several samples of drinking water from Ponderosa Pines and Cloud Country in addition to the samples analyzed in table 5. The drinking water at Ponderosa Pines is more neutral, similar in salt content, and lower in hardness than at Cloud Country (table 6). The lower hardness means there is less Ca and Mg in the Ponderosa Pines water but more Na and K, since the soluble salt content is about the same as Cloud Country.

It appears that runoff waters do not contribute salts to the groundwater; instead, the salts in groundwater results from the type of substratum.

Part III. Evaluation of Institutional Effects

One way of minimizing possible deleterious effects of roads in the forest would be to decrease the amount of roads in subdivision layouts. Some ways of decreasing road surface were investigated by comparing several different layouts on the same piece of ground. Three of these layouts are shown in figures 13, 14, and 15. The traditional "grid" layout was compared to a "curvalinear" design and a "cluster" design. The latter two designs were chosen because of the smaller road-to-lot ratios indicated in a study by the Urban Land Institute (1963). The designs

Table 5. Analysis of precipitation, drinking water, and runoff from Cloud Country

			Runoff			
Component	Precipitation	Drinking Water #1 Well	Gauge 1	Gauge 4	Gauge 5	Gauge 6
pH	6.5	7.6	7.5	7.6	7.8	7.5
Electrical conductivity, μ mhos	.02	.83	.20	.25	.25	.20
Ca meq/ℓ	.10	1.70	1.38	1.84	1.82	1.82
Mg meq/ℓ	.04	7.19	.35	.49	.55	.20
Na meq/ℓ	.06	.50	.15	.15	.18	.12
K meq/ℓ	.03	.02	.14	.05	.05	.04
Sand (2-.05mm)	--	--	9	25	10	12
Silt (.05-.002)	--	--	55	47	57	53
Clay ($<$.002)	--	--	36	28	33	35

Table 6. Comparison of precipitation, drinking water and runoff from Ponderosa Pines and Cloud Country

		Drinking Water*						Runoff				
		Ponderosa Pines		Cloud Country				Ponderosa Pines	Cloud Country			
Component	Precipitation	1 slope	2 well	1 well	2 spring	3 tank	4 house	Gauge 1	Gauge 1 control	Gauge 4	Gauge 5	Gauge 6
pH	6.5	7.1	6.9	7.6	7.5	7.6	7.6	7.5	7.5	7.6	7.8	7.5
Soluble Salt ppm	13	416	435	545	422	400	416	102	128	160	160	128
Soluble Salt meq/ℓ	2	6.5	6.8	8.3	6.6	6.2	6.5	1.6	2.0	2.5	2.5	2.0
Total Hardness as $CaCo_3$ ppm	7	120	160	452	250	245	245	86	83	112	114	97

*Adapted from data supplied by Environmental Improvement Agency, New Mexico

Fig. 13. Grid layout of subdivision. Roads occupy 22.6% of total area. Road area is 29.2% of lot area.

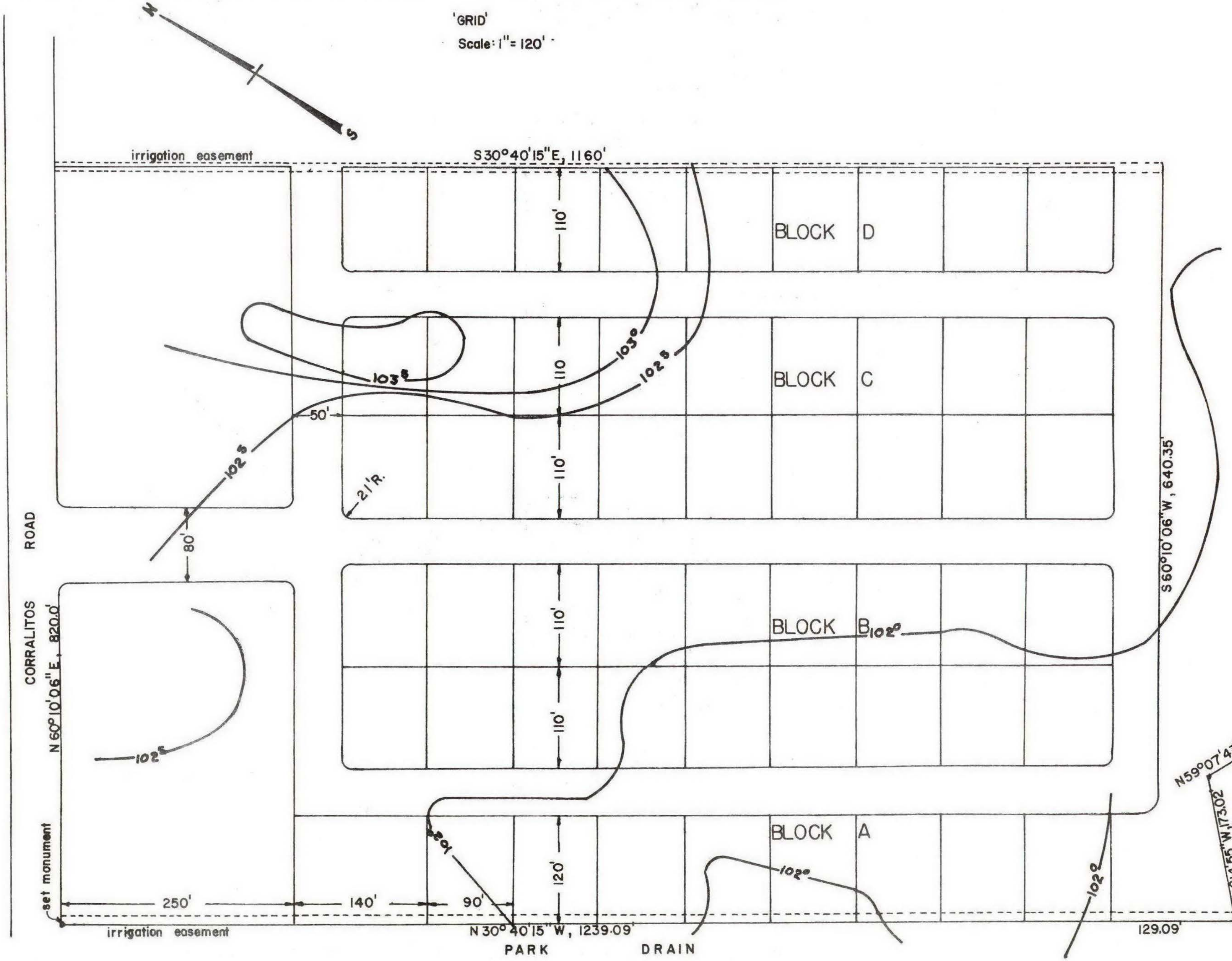


Fig. 14. Curvalinear layout of subdivision. Roads occupy 22.9% of total area. Road area is 29.6% of lot area.

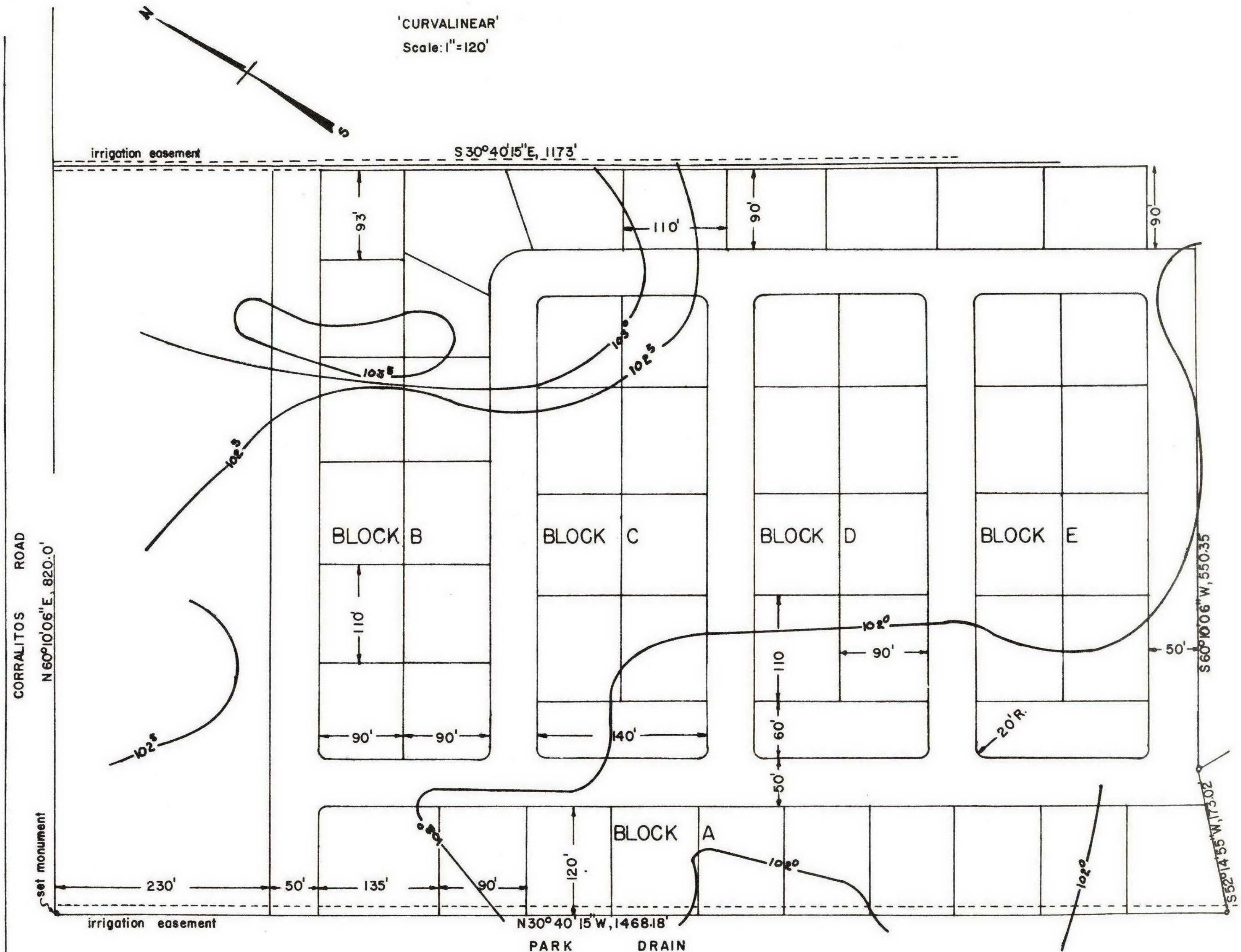
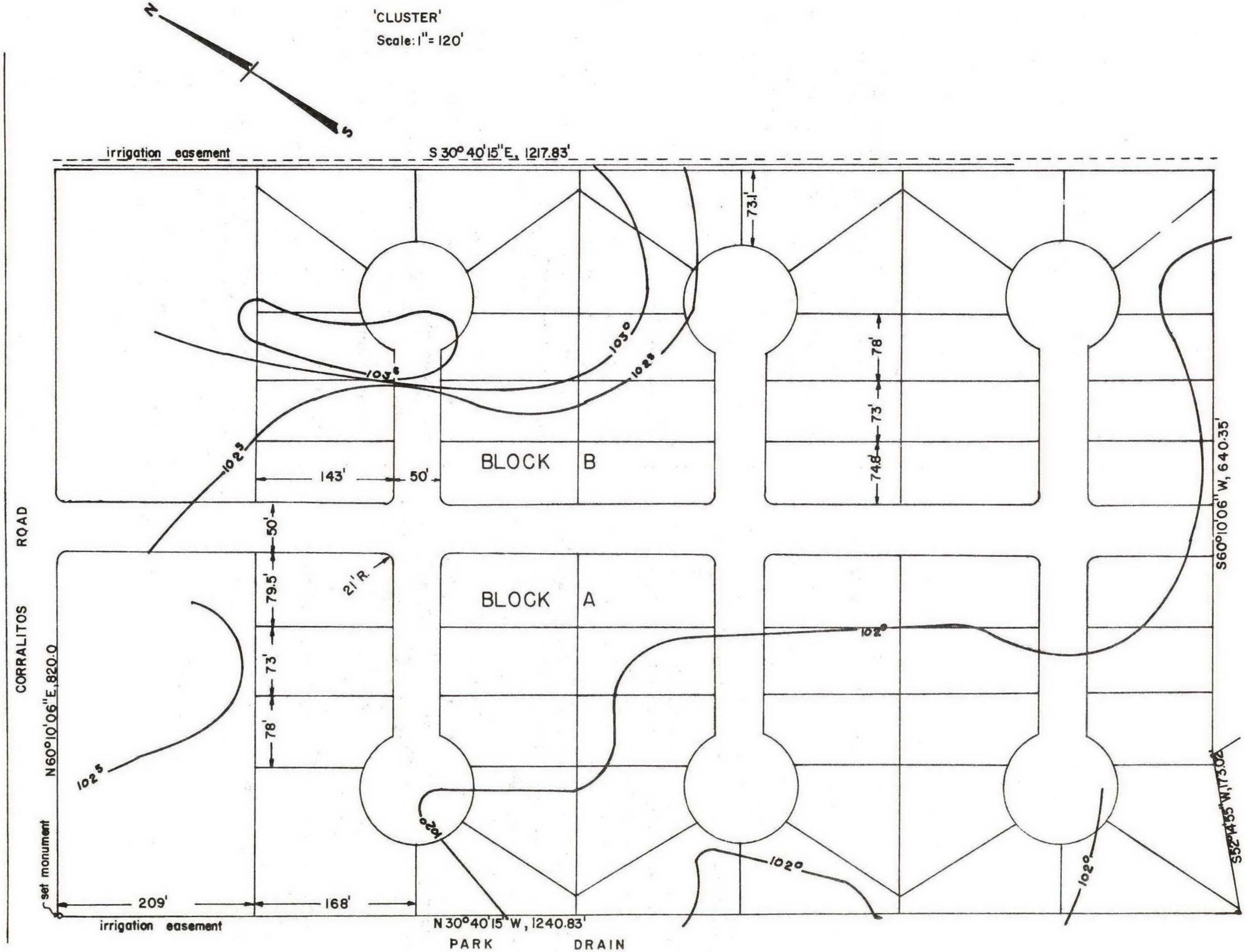


Fig. 15. Cluster layout of subdivision. Roads occupy 19.6% of total area. Road area is 24.3% of lot area.



were each applied to a subdivision which is yet unbuilt. The results are shown in table 7. It is evident from these results that it is possible to decrease the amount of roads in a subdivision by choice of design.

In light of the previously indicated sediment production attributable to utility installation, some consideration must be given to the effect of the subdivision design on these installations. For instance, the "cluster" type of design is obviously superior as far as the road area is concerned for this particular piece of land. Yet, beyond that consideration there is still the choice, at least, between installing the utilities in the road according to the common practice, or carrying the utilities from cluster to cluster. Topography would have a heavy bearing on this decision, so each subdivision would require its own careful study before a choice could be made.

Another institutional effect on the roads in a forest subdivision involves the location of as many as possible of the utilities in the ground. While there are environmental concerns which provide strong motivation for "hiding" the utilities as much as possible, the price associated with this practice is greater sedimentation.

Yet another institutional effect on sedimentation from roads is the type and degree of maintenance provided for the roads. The presence of roads, especially paved roads, creates potentially accelerating erosion in some areas (see figure 7). Prompt and thoughtful maintenance can forestall serious erosion if such maintenance has been provided for in the development plan.

Not all of the powers to prevent road-induced damage to the forest environment rest with developers. Such powers pass with title to the land from the developer to the recreationist. The addition of impervious surfaces such as roofs, paved driveways, and trampled soil and vegetation will add runoff to that already being collected by the roads. Some of this added load can be anticipated and provided for in the subdivision design. But the recreationist should be made aware of the consequences of his presence and accept his share of the responsibility for protecting the true forest environment.

Finally, governmental agencies can, by codes for roads and streets, have desirable or undesirable impacts on the forest. It appears from this study that desirable effects can be obtained by provision for proper maintenance of roads. Also, there should be insistence upon consideration during the planning stages to means of controlling erosion related to utility installation. Undesirable impacts will result from an over-specification in the codes for pavement and other impervious surfaces. Undoubtedly, it will be necessary to accept compromises in the trade-off between some environmental impacts, such as underground utilities and erosion.

Table 7. Comparison of three subdivision designs applied to the same land

Subdivision Design	Acres	Percent of Total	Percent of Lots
Curvalinear			
Streets	5.19	22.9	29.6
Lots	17.53		
Total Area	22.72		
Cluster			
Streets	4.45	19.6	24.3
Lots	18.28		
Total Area	27.72		
Grid			
Streets	4.93	22.6	29.2
Lots	16.89		
Total Area	21.83		

CONCLUSIONS

Recreational developments and the second-home are increasing in popularity, and some type of roads are necessary to provide access to either the development or the homesite. Some soil erosion will inevitably result from road construction. Erosion is most pronounced soon after the road is completed and during periods of construction; e.g., utility installation, and excavations for driveways and homesites.

The forest community appears to buffer the results of construction and in time erosion becomes less pronounced. New construction can reinstitute erosion, but this too will subside in time if proper maintenance is provided.

The erosion resulting from developments in which all roads, driveways, and homesites have been completed cannot be projected from this study. These results only refer to developments that were undergoing the early stages of construction, which mainly included road and utility installations.

In these areas, if some effort is exerted to place long road sections along contours and provide sediment traps (debris), erosion can be minimized.

Further study is indicated to determine the effects of increasing impervious surfaces by the construction of houses and driveways. Also, an exploration is needed for ways of diminishing the detrimental effects of construction of underground utilities.

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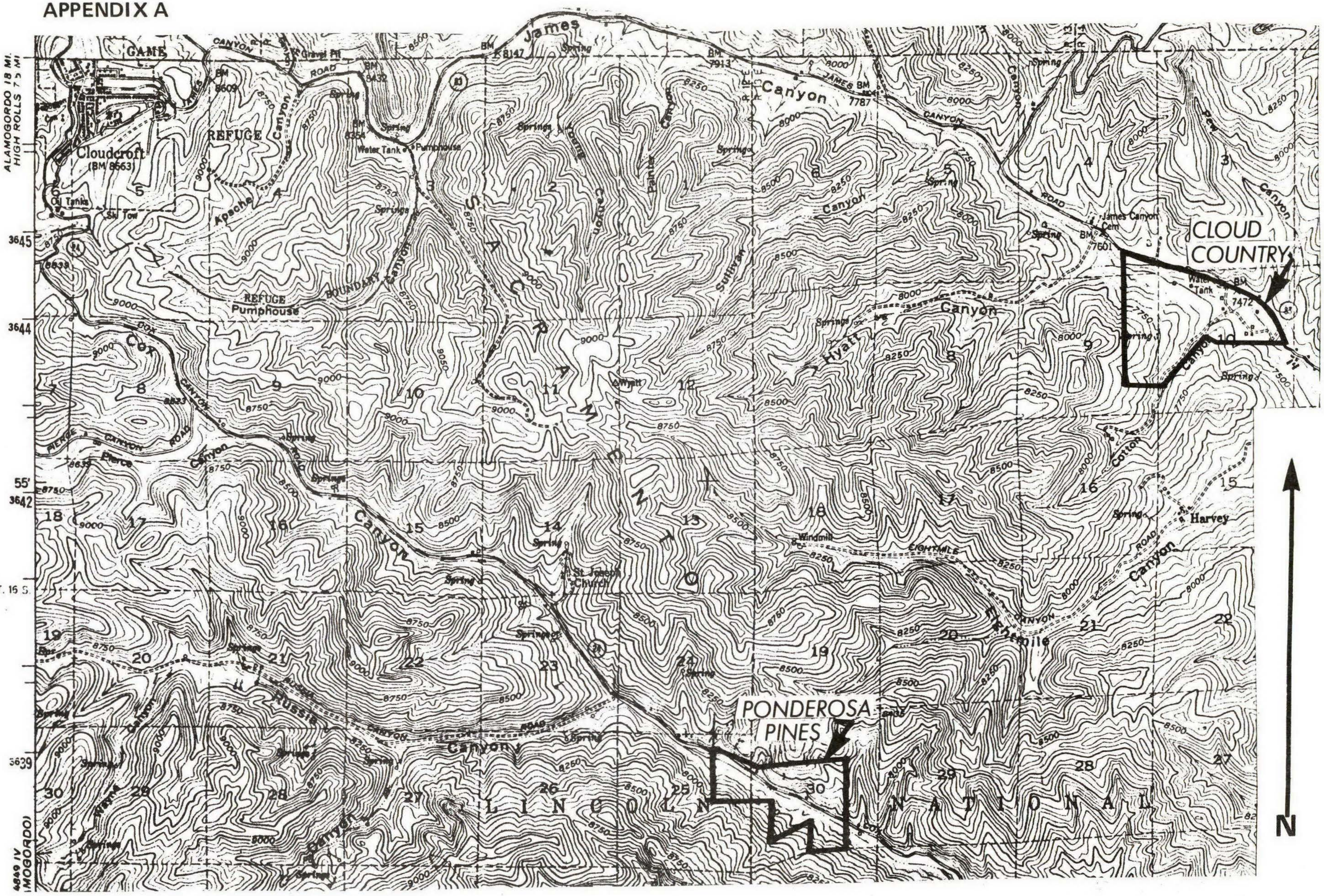
APPENDIX A



CLOUD COUNTRY
PONDEROSA PINES
N
Cloudcroft
(BM 8663)
James Canyon
SACRAMENTO
LINCOLN NATIONAL
Cox Canyon
Russia Canyon
Hyatt Canyon
Eightmile Canyon
Cotton Canyon
Harvey
St Joseph Church
REFUGE
REFUGE Pumphouse
Water Tank
Pumphouse
Windmill